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AMERICAN PHYSICAL SOCIETY

PROGRAM

OF THE

CHICAGO MEETING

NOVEMBER 25–26, 1932

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AMERICAN PHYSICAL SOCIETY

CHICAGO MEETING, NOVEMBER 25–26, 1932

The 180th regular meeting of the American Physical Society will be held in Chicago, Illinois, at the Ryerson Physical Laboratory of the University of Chicago on Friday and Saturday, November 25 and 26, 1932. The first session will be at 10:30 o'clock on Friday morning.

Titles and abstracts of the papers to be presented are given in the following pages. These abstracts have not been corrected by the authors. After correction, they will be published in an early number of the Physical Review. Authors should send corrections to the Editorial Secretary, The American Institute of Physics, 11 East 38th Street, New York, New York.

Dinner. On Friday evening at 7 o'clock there will be a dinner for the members of the Society and their friends in Judson Court across the Midway. The price per person will be $1.50. Tickets should be purchased in the Ryerson Physical Laboratory before 2 o'clock Friday afternoon. In case this is impossible it will be advisable to write in advance for reservations.

Luncheon. Luncheons may be secured at the University Coffee Shop, at the cafeteria in Hutchinson Hall or at Judson Court.

Headquarters. Judson Court one of the college residence halls located across the Midway between Ellis and Greenwood Avenues has been selected as headquarters. The rates for single rooms will be $2.00 per night and for suites consisting of bedroom, living room and private bath $5.00 for one person or $3.00 each for two. Members of the Society will be housed in an entry together so that they will have the privilege of association with their own group. Meals will be available in the dining hall as the members wish to take them at $.50 for breakfast and $.60 for lunch. There will be adequate provision for headquarter rooms, lounges and conference rooms. The Society banquet will be served here on Friday evening. There are a few suites in Judson Court dormitories with private baths which would be available for men accompanied by their wives. It is not necessary to make reservation before arrival at Judson Court but preference in location of room will be given to those who do maks reservations in advance.

For those not wishing to go to Judson Court we suggest the Hotels Windermere at 1600 East 56th Street where the rates are $2.50 for single room and

$5 00 for double rooms in Windermere East, and $2.00 for single rooms and $3.00 for double rooms in Windermere West. For those wishing to stop at a downtown hotel we suggest the Congress where the rates are $3.50 for single rooms and $5.00 for double rooms. The Congress Hotel will make arrangements to have bus service from the hotel to the University in the morning and return trip in the afternoon at the rate of ten cents per person.

CALENDAR

Friday morning at 9:30 o'clock, Room 316, Eckhart: Meeting of the Council
Friday morning at 10:30 o'clock, Room 133, Eckhart: Papers 1–9
Friday afternoon at 2:00 o'clock, Room 133, Eckhart: Papers 10–21
Friday evening at 7:00 o'clock, Dinner at Judson Court
Saturday morning at 10:30 o'clock, Room 133, Eckhart: Papers 22–30
Saturday afternoon at 2:00 o'clock, Room 133, Eckhart: Papers 31–39
Saturday afternoon at 2:00 o'clock, Room 32, Ryerson: Papers 40–49.

The supplementary papers beginning with No. 50 may be called for at the end of any one of the sessions held in Room 133, Eckhart.

Atlantic City Meeting. The preliminary arrangements for the Atlantic City program include a joint session with the American Mathematical Society at the time of the Josiah Willard Gibbs lecture by Professor R. C. Tolman on Thursday afternoon, December 29th, at four-thirty o'clock, and a joint session with Section B of the A.A.A.S. and the American Meteorological Society at which time the Retiring Vice-President of Section B, Professor Bergen Davis, will deliver an address.

A symposium has been arranged on "Cosmic Rays" at which the speakers will be Professor A. H. Compton, Dr. Gordon L. Locher, Professor R. A. Milliken and Dr. H. Victor Neher.

Headquarters. The Ambassador Hotel on the Boardwalk has been selected for hotel headquarters for the American Physical Society at Atlantic City. Members are urged to make their reservations at once (writing directly to the hotel).

The rates at the Ambassador are: single rooms, $4.00 to $5.00 per day; double rooms, $6.00 to $10.00 per day.

Members intending to present papers at this meeting should have the typewritten titles and abstracts (not exceeding 200 words) ready for publication, in the hands of the Secretary not later than Thursday, November 17th.

Other meetings for the current season are as follows:

181. Pasadena. December 16–17, 1932. Pacific Coast.
182. Atlantic City. December 28–30, 1932. Annual Meeting.
183. New York City. February 23–25, 1933. Joint meeting with Optical Society of America.
184. Washington, April 27–29, 1933.
185. June, 1933. Pacific Coast. Time and place to be announced later.
186. Chicago. Week of June 19, 1933.

W. L. SEVERINGHAUS, *Secretary*
Columbia University, New York, N. Y.

November 7, 1932

PROGRAM

FRIDAY MORNING AT 10:30 O'CLOCK

Room 133—Eckhart

1. The magnetic susceptibilities of some common gases. G. G. HAVENS, *University of Wisconsin.*—In view of the large differences among the results of various observers for the magnetic susceptibilities of common gases, it seemed desirable to apply to some of these gases the method described in a previous article. (Phys. Rev. **41,** 339 (1932)). Being a comparison method, the values obtained are relative to a provisional value of $X_{O_2}=3335\times10^{-6}$ for the molecular susceptibility of oxygen at 20°C. If the value for oxygen should later prove to be different, the values for these gases will be changed proportionally. The results obtained are: $X_{H_2}=-4.014\times10^{-6}$, $X_{He}=-1.925\times10^{-6}$, $X_{N_2}=-11.94\times10^{-6}$, $X_{CO_2}=-20.81\times10^{-6}$. The results for H_2, He and N_2 are in good agreement with those obtained by Wills and Hector. (Phys. Rev. **23,** 209 (1924).) The value of the temperature presented the largest uncertainty in the measurement of susceptibilities at liquid air temperatures; however it was found that the molecular susceptibilities of H_2 and He at liquid air temperatures vary less than 4 percent from those obtained at room temperatures. This result disagrees with that of Bitter (Phy. Rev. **36,** 1648 (1930)) which indicates a decrease of more than 40 percent in the molecular susceptibility of H_2 in going from room to liquid air temperatures. Preliminary observations indicate that the susceptibilities of ortho- and para-hydrogen are the same within 1 percent.

2. The paramagnetic susceptibility of Cu^{++}. O. M. JORDAHL, *University of Wisconsin.*—Calculations have been made for the susceptibility of the Cu^{++} ion subject to a crystal potential field of predominantly cubic symmetry with a small rhombic field superposed. The Hamiltonian is

$$Ax^2+By^2-(A+B)z^2+E(x^4+y^4+z^4)+\lambda(\boldsymbol{L}\cdot\boldsymbol{S})+\beta(\boldsymbol{H}\cdot\boldsymbol{L}+2\boldsymbol{S})$$

By proper choice of the parameters, the resulting expressions for the principal susceptibilities are capable of agreement with the known experimental data. To a good approximation, the expression for the mean (i.e. powder) susceptibility X_m is independent of both the magnitude and the asymmetry of the rhombic field, and gives a linear dependence on temperature for the quantity $(X_m kT/N\beta^2)$. This agrees with the Leiden data of de Haas and Gorter on $CuSO_4\cdot5H_2O$ from 14°K to 290°K. In order to fit the data of Bartlett on the principal susceptibilities of $Cu(NH_4)_2(SO_4)_2\cdot6H_2O$ and $CuK_2(SO_4)_2\cdot6H_2O$ (Phys. Rev., **41,** 818 (1932)) it is necessary to choose the parameters so that the cubic field produces a splitting of approximately 20000 cm^{-1} and the splitting of the lower cubic level by the rhombic field is about 300 cm^{-1}. These values agree approximately with those found for Co, Ni and Cr by R. Schlapp and W. G. Penney. (Phys. Rev., in press.)

3. A compact high potential electrostatic generator. HENRY A. BARTON, *American Institute of Physics,* D. W. MUELLER, *Princeton University and* L. C. VAN ATTA, *Massachusetts Institute of Technology.*—An inexpensive and compact continuous high-potential source was desired for nuclear research. A Van de Graaff, belt-type, electrostatic generator has been built. To overcome the corona limitation due to high potentials and small dimensions, the entire apparatus is mounted in a cylindrical steel drum and the insulating air raised to a pressure of several atmospheres. A cylindrical electrode is supported in the center of the drum by two textolite cylindrical tubes of the same diameter. In one of these runs a silk charging belt similar to that in the original Van de Graaff generator. The other supporting tube can be evacuated and it will be used in applying high potentials to the acceleration of charged particles. At a pressure of seven atmospheres, a potential of about one million volts was generated. High pressures also permit greater charge to be carried on the belt. In a separate test, also at seven atmospheres pressure, the belt transported charge at the rate of 0.1 m.a. It will be possible to operate at twice the pressure so far used. The belt can be driven twice as fast as now and a parallel belt added. It is hoped to generate a kilowatt at about two million volts.

4. The production of high velocity protons by repeated accelerations. A. J. DEMPSTER, *University of Chicago.*—The principle of a simple method for repeated acceleration of canal rays has been tested. The positive rays from a high potential hydrogen discharge tube pass into hydrogen at higher pressure where some of the atoms become neutral and the equilibrium ratio between positive and neutral particles is approached. The neutral rays then cross a high retarding field into a positively charged metallic chamber 32 mm long connected to the anode. During their passage through this chamber, at a pressure of 0.2 mm Hg, a number of the neutral atoms revert to the positively charged state. On leaving the positively charged metallic chamber, these positively charged atoms are accelerated and attain twice their original energy. The process may be repeated indefinitely with a loss of intensity at each passage through an accelerating chamber. An experiment was carried out with one acclerator in which the energy of the rays was deduced from the deflection, by a short transverse electric field, of the spot produced by the rays on a fluorescent screen. With the accelerator grounded a maximum energy of 22,500 volts was observed, and with the accelerator joined to the anode of the discharge tube a new spot appeared with half the deflection, corresponding to an energy of 45,000 volts.

5. Polarization of collecting electrodes in high vacua. A. E. SHAW, *University of Chicago*—In an experiment to determine e/m by electron deflection in superimposed electrostatic and magnetic fields, it was found possible to determine accurately the value of the surface charges that form on the plates to which the electric potential is applied and which must be corrected for. These surface layers have been found to vary with the material of the plates, the gas pressure and the intensity of the electron beam. They are independent of the intensity of the electrostatic field. With bronze at pressures of 5×10^{-7} mm Hg and an electron current of 3×10^{-12} ampere, the surface potential was 0.263 volt. With a current of 10^{-1} ampere the pressure remaining the same, the potential increased to 0.998 volt. With gold the surface potential was less than 0.005 volt, at pressures of 5×10^{-7} mm Hg and an electron current of 3×10^{-12} ampere.

6. Ionization of He by electron impact. W. W. WETZEL, *University of Minnesota.*—The Born collision theory (neglecting exchange effects) is applied to the ionization of He by electron impact. The distributions in angle and energy of the scattered electrons have been calculated for initial electron energies of 50, 100, 200, and 500 volts. The curves are in qualitative agreement with the experiments of Van Atta in He for the distribution in energy and with those of Tate and Palmer in Hg for the angular distribution. The most probable mode of ionization is for scattering in the forward direction with a loss of about one volt energy, the probability dropping rapidly to zero just at the ionization potential. The theoretical curves show, however, a continually increasing total probability of ionization due to excessive scattering in the forward direction. To obviate this difficulty the distortion of the wave forms of the incident and scattered electrons is being studied. Preliminary considerations indicate also a reasonably good probability for ionization and simultaneous excitation in He.

7. Ionization by electron impact in water vapor and sulphur dioxide. H. D. SMYTH AND D. W. MUELLER, *Princeton University.*—Ionization in water vapor and sulphur dioxide has been studied with the mass spectrograph previously used by Smyth and Stueckelberg. In water vapor the results of previous investigators have been confirmed and extended. Two I.P.'s for H_2O^+ were found, 12.7 ± 0.3 and 16.0 ± 0.6 volts. Other positive ions in much smaller numbers appeared as follows: H^+ at 18.9, OH^+ at 18.9, H_3O^+ with H_2O^+, O^+ at 18.5, H_2^+ at 33.5 and O_2^+ (very weak). In sulphur dioxide which has apparently never before been studied, SO_2^+ ions appeared at 13.1 ± 0.3 volts. SO^+ ions at 16.5 ± 0.5 and ions of mass 32, either S^+ or O_2^+, at 16.0 ± 0.7, increasing sharply at 22.3 ± 1.0. No O^+ ions were observed. The existence of a strong second I.P. for H_2O^+ had been suggested by Smyth and Stuckelberg on experimental grounds and by Mulliken for theoretical reasons. Consideration of the probable ionization processes corresponding to the other results shows one point of special interest. Evidently the processes $H_2O\rightarrow H_2+O^+$ and $SO_2\rightarrow S^++O_2$ both occur and at very nearly the minimum energy calculated. This means that in the process of ionization not only are the chemical bonds between the O (or S) and H (or O) atoms broken but new bonds are established between the H (or O) atoms themselves which did not exist in the normal state.

8. Radiation excited by canal ray impact. F. L. VERWIEBE, *University of Chicago.*—Hydrogen canal rays accelerated in a field up to 50 kv were allowed to impinge on a metal target, and the beam of particles and radiation emitted from the target was investigated. Pinhole images of the focal spot were obtained on Schumann plates and plates coated with molybdenum tri-oxide. The tri-oxide indicates the presence of atomic hydrogen. By means of a deflecting magnetic field it was found that the beam coming from the target consisted mainly of neutral particles or of radiation, and also of a fainter beam of protons which had a velocity practically equal to that of the protons in the incident canal rays. The presence of uncharged hydrogen atoms in the neutral beam was shown by the image of characteristic light blue color formed on a molybdenum tri-oxide plate. A grating was used to determine whether the undeflected beam also contained electromagnetic radiation. A diffraction pattern was obtained and the value of the wavelength was found to agree within the limits of the accuracy of the measurements with that of the first Lyman line, 1216A′. No wave-lengths shorter than this of observable intensity were found.

9. Radiation from positive ions in argon, neon, helium. A. I. MCPHERSON, *University of Chicago* (*Introduced by A. J. Dempster*).—Light excitation was produced by a stream of high speed—20,000 volt—positive ions of argon, neon, helium in passage through rarefied argon, neon, helium respectively. The spectra observed in the direction of motion show groups of doublets, whose separation varies with the velocity of the positive ions, a sharply marked Doppler displacement. In argon and neon, the first spark lines are strongly excited in both the gas at rest and in the moving particles, the intensity of the displaced line in each doublet being only slightly less than that of the undisplaced line. The arc lines appear relatively weak, an in the very few cases where an arc line has an accompanying Doppler line, it is very faint indeed. In helium many of the lines of both arc and spark spectra show the effect clearly but the intensity of the displaced line is usually much less than that of the rest line, and the relative intensity varies greatly from line to line.

FRIDAY AFTERNOON AT 2:00 O'CLOCK

Room 133—Eckhart

Papers No. 10 and 11 will be read by title.

10. The actinium branching ratio. FORREST WESTERN AND ARTHUR RUARK, *University of Pittsburgh.*—The actinium branching ratio is $\lambda_{Ac}N_{Ac}/E$; $\lambda_{Ac}N_{Ac}$ is the activity of the actinium in equilibrium with a sample of uranium of activity $2E$. Assuming one or two actino-uranium isotopes, the ratio $B=\lambda_{Ac}N_{Ac}/\lambda_1N_1$ is more useful. (Subscripts 1, 2, 3, 4 refer to isotopes 238, 234, 239, 235.) B is determined from the saturation currents i_{Ur} and i_{Pa}, from a sample of uranium and its associated protoactinium, and the alpha particle ion numbers k_{Pa}, k_1, $\cdots$ k_4. Ziegert's determinations of ion numbers and the above actinouranium hypothesis, necessitate revision of branching ratios given by Widdowson-Russell and Hahn-Meitner. Assuming two actinouranium isotopes of masses 235 and 239, we find that

$$B=[(k_1+k_2)i_{Pa}]/[k_{Pa}i_{Ur}-(k_3+k_4)i_{Pa}].$$

If Ur_3 does not exist, put $k_3=0$. k_1, k_2 and k_{Pa} are known. It seems probable from work of Ziegert and of Wilkins-Rayton that $k_3 \leqq k_4 \leqq k_2$. If so, data of Widdowson-Russell and Hahn-Meitner yield $B=0.0281$ or 0.0320 if Ur_3 is non-existent; and $B=0.0285$ or 0.0325, if Ur_3 exists. Data of Wildish are not appreciably affected; von Grosse, details unpublished, obtained 0.04.

11. The atomic weights of radioactive substances. FORREST WESTERN AND ARTHUR RUARK, *University of Pittsburgh.*—Given the isotopic weights of RaG, AcD, and ThD, that of any other radioactive substance can be obtained by adding the masses of the particles emitted and the mass equivalent of the energy lost, in the intervening disintegrations. Such computations were made by St. Meyer but we do not agree with all his conclusions. Using Aston's analyses of leads, chemically-determined atomic weights, and the packing fraction curve, one finds in three ways that the weight of Pb^{216} is 205.984 ± 0.03 on the chemical scale. The weights

of Pb^{207} and Pb^{208} are assumed to differ from this by integers, by analogy with the behaviors of Hg and Kr. We then obtain the following isotopic weights.

	Calculated	Accepted Chemical Value
Radium	226.027	$225.96_7 \pm 0.012$
Protoactinium	231.039	
Ur^{234}	234.040	
Ur^{235}	235.045	
Ur^{238}	238.046	$238.13_7 \pm 0.013$ (Ur mixture)
Ur^{239}	239.051	
Thorium	232.035	232.120 ± 0.014

Any reasonable assumption as to half-lives of possible actinouranium isotopes yields an atomic weight for Ur unreconcilable with that obtained chemically. The calculated atomic weights of Ra, Th, and Ur should be used in preference to currently accepted values.

12. Argon in the ionization method of measuring cosmic rays and γ rays. JOHN J. HOPFIELD, *Basic Science Division, A Century of Progress, Chicago.* (*Introduced by H. G. Gale.*)—Ionization current-voltage curves of argon at 31 atm. and 71 atm. and at four γ-ray intensities of ratios 1, 10, 100 and 1000 were not convertible into one another by constant factors. The superiority of argon over air for ionization chambers, and the slower recombination of its ions is shown in the following:

Pressure in atm.	10	20	30	40	50	60	70	80	90	100
I, ions/cc/sec per atm, (argon)	3.75×10^2	3.45	3.09	2.80	2.57	2.36	2.19	2.03	1.89	1.77
I, ions/cc/sec per atm, (air)	1.80×10^2	1.44	1.18	1.02	0.90	0.80	0.71	0.65	0.59	0.55
$I_{argon.}/I_{air.}$	2.08	2.40	2.61	2.73	2.84	2.95	3.05	3.12	3.18	3.23

It is seen from these data that the argon ionization-pressure curve is more nearly linear than that of air; furthermore the argon curve is rising rapidly even at the end pressure. Preliminary results indicate that the ratio of intensity of cosmic rays to γ-rays is a function of the argon pressure. At 36 atm. it was 0.117, and at 74 atm., 0.139. This change could be accounted for by insufficient voltage for saturation. A smaller ratio of cosmic rays to γ-rays was measured in argon (0.117) than in air (0.149), at the same pressure. This seems to be the first direct comparison of the action of cosmic rays on monatomic and diatomic gases. This smaller ratio accords with the suggestion that the primary attack of cosmic rays is on atomic nuclei, since argon has half as many as air. Other explanations are tenable. These experiments were carried out through the courtesy of the University of Chicago.

13. Sea level intensity of cosmic rays in certain localities from 46° South to 68° North latitude. ARTHUR H. COMPTON, *University of Chicago.*—Measurements have been made, with the help of many cooperating physicists, of the cosmic rays at typical stations in Hawaii, New Zealand, Australia, east and west equatorial Pacific ocean, Panama, Peru, Mexico, United States, Canada and Switzerland. When reduced to normal barometric pressure, or sea level, these data show nearly uniform intensity for latitudes north of 34° in United States and south of 34° in Australasia. Between these latitudes the intensity drops sharply to a value about 87 percent as great as that in the temperate zones. As compared with northern North America, northern Europe has sensibly the same intensity of cosmic rays, while the data indicate that in temperate Australasia the intensity is 2 or 3 percent greater. These data are probably in error by about 1 percent. A comparison of the data taken in Peru and Mexico shows a much closer correlation of the intensity of the cosmic rays with the dip of the magnetic needle than with the geographic latitude. The differences in intensity thus seem to be due to the earth's magnetic field, which would seem to imply that the cosmic rays are electrical in character.

14. Diffraction of low speed electrons by a tungsten single crystal. WAYNE T. SPROULL, *University of Wisconsin.*—The (1–1–2) and (1–0–0) planes of a tungsten crystal were bombarded at normal incidence with primary electrons and the intensity of the full-velocity secondary beams measured as a function of azimuth, co-latitude (θ), and primary voltage. A new magnetic deflection method of analyzing the secondaries permitted observations at co-latitudes down to zero. The crystal was outgassed 1550 hours at temperatures up to 1600°C at pressures of 10^{-7} mm of Hg or less. Beams fitting the usual theory were found for the (1–1–2) plane in the azimuth parallel to the diagonals of the lattice cubes, but in the azimuth (A) perpendicular at the cube diagonals strong sharp beams were found at every primary voltage tried, their

positions accurately obeying the volume law $n\lambda = d/\sqrt{6} + 2d/\sqrt{6} \sin(30° - \theta)$ after making the usual allowance for the work function W_a. Beams found in the (1–0–0) plane obeyed the usual theory, except that during growth and decay they also obeyed the volume law and not the surface law. W_a was 4.56 volts for $\theta = 0$ and increased with θ. The effect of variation of angle of incidence was briefly studied. A possible explanation of the peculiar behavior of the beams in the A azimuth of the (1–1–2) plane is outlined.

15. Intensity distribution in electron diffraction patterns of ZnO. H. J. YEARIAN AND K. LARK-HOROVITZ, *Purdue University.*—A well defined electron beam from a hot filament has been used in the range between 3.3 and 25 kv for the production of diffraction patterns of ZnO powder. Purest ZnO has been prepared directly on the slit using a zinc arc, or has been deposited chemically. The geometry of the diffraction pattern is identical with the corresponding x-ray pattern, giving C^4_{6v}, $a = 3.22$ A°, $c/a = 1.61$; there appear however also forbidden lines (fractional orders). The intensity distribution shows marked deviations from the intensity distribution of the x-ray patterns. It has been shown that these deviations are not due to pre-

hkl	$10\bar{1}0$	0002	1011	1012	1120 ···	$11\bar{2}4$	1232
Elec. Int.	St.	V.V.St.	V.St.	V.St.	St.	F	V.St.
X-Ray Int.	St.	Med.	St.	Med.	St.	F	F

ferred orientation, differences in structure due to methods of preparation, or coincidences with another form of ZnO. The theoretical explanation of the F curves thus obtained is discussed on the basis of additional surface reflection, dynamic reflection, and finally under the assumption that nuclear parameter is slightly greater than the electronic parameter. A partial explanation of the intensity distribution on this basis is possible.

16. Deflection of a beam of HCl molecules by a non-homogeneous electric field. EDWIN MCMILLAN, *Princeton University.*—It was found possible to use a film of ammonia frozen on to a polished metal surface by liquid air as a quantitative detector for a beam of HCl; this was done by putting a number of exposures on the target during each run to serve as intensity marks, and photographing and photometering the resulting deposits of NH_4Cl. The intensity distribution in a beam broadened by passage through a nonhomogeneous electric field was measured by this means, and found to agree with the theory. An attempt was made to resolve the deflected beam into components by the use of a mechanical velocity filter. This failed because of lack of intensity of the beam after filtration.

17. A determination of e/m by means of photoelectrons excited by x-rays. G. G. KRETSCHMAR, *University of Chicago.*—A value of e/m has been obtained by a magnetic deflection method making use of x-ray photoelectrons and the magnetic spectrograph. Electrons were ejected from thin evaporated or sputtered films of gold, silver, copper and platinum by the x-radiation from a molybdenum target metal tube placed close to the film and working at an input of 1.5 kilowatts. The velocity of ejection of the photoelectrons was computed from the difference between the energies associated with MoK radiation and the various absorption limits of the sputtered films. Relativity corrections were made since these velocities correspond to 8000 to 15000 equivalent volts. The α_1 and α_2 components of the molybdenum $K\alpha$ line were clearly resolved since the magnetic field was kept very constant by the use of a potentiometer and continuous hand control. The weighted mean value of e/m_0 obtained from five plates is $1.7555 \pm .0026 \pm 10^7$ e.m.u. per gram. It is to be noted however, that the absolute accuracy of this result is dependent upon the values of x-ray wave-lengths from crystal measurements.

18. Theory of the energy distribution of photoelectrons. LEE A. DUBRIDGE, *Washington University, St. Louis, Mo.*—The success of Fowler's theory in predicting the form of photoelectric spectral distribution curves at various temperatures leads one to expect that similar methods would yield expressions for the energy distribution and voltage-current curves. Considering first only the energies normal to the surface (plane parallel electrodes) and using the Fermi statistics, an expression has been derived for the voltage-current curve which is identical with Fowler's equation for the total emission, except that the surface potential jump W_a is replaced by $(W_a + Ve)$ where V is the retarding potential. The theoretical curve is in good agreement with preliminary experimental results, and yields a method of determining the maximum

emission energy at 0°K. At all higher temperatures the voltage-current curves should approach the axis symptotically. This has an important bearing on the photoelectric determination of h. When the total energies of the emitted electrons are considered a more complex expression results, which can, however, be put in a form for comparison with experiment. The predicted curve is widely different from those usually observed experimentally, and experiments are under way to determine the cause of the discrepancy.

19. Energy distribution of secondary electrons from molybdenum. L. J. HAWORTH, *University of Wisconsin.*—A careful study has been made of the distribution in energy of secondary electrons emitted by a thoroughly outgassed Mo target when bombarded with a narrow, homogeneous beam of primary electrons. As observed by Farnsworth, Soller, and others, two groups of secondary electrons predominate; the usual large group of "full velocity" secondaries of energy equal to that of the primaries, and an equally large group of very slow secondaries of energy from zero to 15 volts. In addition to the general distribution several small groups of secondaries may be distinguished. These may be divided into two classes: (1) groups similar to those reported by Rudberg (P.R.S. **127,** 111 (1930)) consisting of electrons of energies certain fixed amounts less than that of the primary electrons; (2) groups of electrons of fixed energy relative to the absolute scale, independent of the energy of the primary electrons. A study was also made of the number of "full velocity" secondaries as a function of primary energy. An attempt has been made to explain the results obtained on the basis of theory developed by Kronig, Penney, and others, relative to allowed energy levels for electrons in a metallic lattice.

20. Scattering of slow electrons by caesium ions. C. BOECKNER AND F. L. MOHLER. *Bureau of Standards, Washington, D.C.*—Measurements were made of the gradient and the temperature and concentration of the electrons in the positive column of a caesium vapor discharge. From such measurements the electron mobility and the effective cross-section of the caesium atoms for electron scattering can be deduced. (T. J. Killian, Phys. Rev. **35,** 1238 (1930).) It is found that the scattering cross-section increases linearly with electron concentration, the increase being very rapid for low pressures. The variation at all caesium pressures can be explained by the assumption that scattering is due to the sum of the effects of the ions and neutral caesium atoms. The cross-section of ions for the interception of slow electrons (0.3 volts) obtained by means of this assumption is very large, 80×10^{-14} cm². The cross-section of the neutral atoms is 3.8×10^{-14}, a value in fair agreement with that obtained from more direct measurements. The large cross-section of the ions can be explained by the ordinary electrostatic attraction between particles of opposite charge. A 0.3 volt electron, for example, whose original direction of motion passes 40A from an ion is deflected through 60° by the action of the electrostatic forces.

21. The scattering of lithium ions from a nickel surface. ANDREW LONGACRE, *Princeton University.*—The velocity and intensity of lithium ions scattered from a metal surface have been measured by allowing the ions scattered to pass through openings into a Faraday collector. The source (heated spodumene) and collimating apertures could be rotated around the target so that the latter could be bombarded from any arbitrary angle. The Faraday collector was supported rigidly in order to obtain satisfactory insulation and the angle of scattering varied by rotating the source and target together. With a homogeneous initial beam the ions are scattered in the general direction corresponding to the specular reflection of light. There is no evidence of a general scattering obeying a cosine law. In the immediate neighborhood of maximum intensity the scattering obeys a form of cosine law. By means of retarding potentials the energies of the scattered ions was measured and the scattered beam was found to have a more homogeneous distribution the greater the angle of scattering. The most probable energy, E, of the scattered ions varies with the angle of scattering, θ, and may be expressed by the following relation, $E=a\theta+b$, where a is a constant depending only upon the angle of incidence and b is a constant depending upon the incident energy as well as upon the angle of incidence.

SATURDAY MORNING AT 10:30 O'CLOCK

Room 133—Eckhart

22. The behavior of crystalline test bodies in streaming solutions. T. W. MOORE, *Purdue University, (Introduced by K. Lark-Horovitz).*—The change in shape of test bodies of rock salt in NaCl solutions of various concentrations and flowing with different velocities has been studied. In dilute solutions the influence of the solubility of the salt is prevalent. In more concentrated solutions the test body assumes the shape determined by the hydrodynamic forces exerted on the material by the streaming liquid. In saturated solutions the test body assumes a shape which is practically determined by the hydrodynamic forces only: stream-line profile. The results are applied to the observations on the erosion of natural rock and technically used material.

23. The electrical properties of surface layers. K. LARK-HOROVITZ AND J. E. FERGUSON, *Purdue University.*—With a polonium electrode as a sounding device, the potential at the interface air-liquid has been investigated for pure water, electrolyte solutions and monomolecular layers of stearic and oleic acid spread on the surface of electrolytic solutions. It has been found that the surface of electrolyte solutions in pure water is not consisting of a pure water layer, but that ions are diffusing into the surface layers (Behavior in HCl, NaOH, NaCl solutions). The monomolecular layers of stearic and oleic acid act like solid electrolytes, behaving in acid solutions like a hydrogen electrode and in alkaline solutions like a sodium electrode. The surface of pure water which has not been cleaned as for surface tension experiments appears to be covered with a film of organic substance acting like the fatty acid mentioned above. The phenomena observed with these layers present a striking analogy to the phenomena observed with glass, quartz, and paraffin films.

24. The cybotatic condition of ethyl ether in the region of the critical point. ROSS D. SPANGLER, *The State University of Iowa.*—X-ray diffraction curves of ethyl ether are taken at various temperatures, pressures, and specific volumes with special emphasis in the region of the critical point. With constant pressure and increasing temperature and specific volume, the diffraction curve changes from that typical of a liquid, with a pronounced peak, signifying cybotactic molecular grouping, to that typical of a polyatomic gas with no peak signifying randomly arranged molecules. The peak disappears approximately at the critical volume but not at the critical temperature. At intermediate temperatures and specific volumes, the curve is a composite of a gas and a liquid curve indicating that some of the molecules are in groups and others are randomly arranged. Within the present range of pressures, the type of curve obtained does not change with temperature if the specific volume is held constant. For example, no difference is found between curves taken at ten degrees above and below the critical temperature of 194.6°C. Beyond a certain specific volume, approximately the critical one, no indications of groups are found and the type of curve obtained is independent of temperature pressure, and specific volume within the ranges used.

25. On the process of liquefaction. G. W. STEWART, *University of Iowa.*—The paper at this meeting by Spangler calls attention to a necessary revision in current ideas concerning liquefaction. It has long been thought that liquefaction is dependent upon some type of aggregation of molecules. It is now seen that while well-defined aggregates are essential to liquefaction, yet they exist also under other conditions, for example at a higher temperature and less specific volume than the critical values. The process of liquefaction does not require an increase in the number of molecules per cm^3 in the cybotactic groups. It may occur with the number of aggregated molecules either constant or decreasing and pressure and temperature decreasing. The extent of the groups depends most importantly upon the specific volume. Liquefaction depends most importantly on the possible existence of a second fluid phase in equilibrium and not as directly upon aggregation as formerly supposed.

26. Diffuse scattering of x-rays from a complicated crystal. G. E. M. JAUNCEY AND PAUL EHRENFEST II, *Washington University, St. Louis.*—Jauncey has recently obtained a formula for the diffuse scattering of x-rays from a crystal consisting of different kinds of atoms and possess-

ing a lattice of any kind. In order to test this formula we have measured the diffuse scattering of x-rays from calcite at various angles. We find that the S curve for calcite falls between the S curve for sodium fluoride and that for sylvine and close to the S curve for rocksalt. This is as it should be according to the theory. Another interesting point is that the intensity of the diffuse scattering from a crystal does not depend upon the perfection of the crystal as is the case for Bragg reflection—calcite being a nearly perfect crystal and rocksalt a very imperfect (or mosaic) crystal.

27. Diffuse scattering of x-rays from an NaF crystal at low temperatures. P. S. WILLIAMS AND G. E. M. JAUNCEY, *Washington University, St. Louis.*—Using the photographic method described by Jauncey and Harvey, we have obtained for each of several scattering angles the ratio of the intensity of x-rays diffusely scattered from a crystal of sodium fluoride at the temperature of dry ice in butyl alcohol (about $-70°$C in the apparatus used) to that of the rays scattered from the same crystal at room temperature ($+22°$C). The value of $(\sin \frac{1}{2}\phi)/\lambda$ was found for each angle of scattering. The ratios are as follows, the first of each pair of numbers being the value of $(\sin \frac{1}{2}\phi)/\lambda$: 0.14, 0.932; 0.27, 0.917; 0.41, 0.919; 0.54, 0.931; 0.67, 0.947; 0.80, 0.973; 0.93, 0.980. The experiment is being continued with the crystal cooled to the temperature of liquid air.

28. The relative intensities of the $L\alpha_1$ and $L\beta_2$ lines in the fluorescent x-ray spectrum of uranium. REGINALD J. STEPHENSON, *University of Chicago.* (*Introduced by S. K. Allison.*)—Radiation from a metal x-ray tube with a molybdenum target fell on a secondary radiator of uranium and excited its fluorescent spectrum. The Mo K lines lie between the L_{II} and L_{III} absorption limits of uranium, hence the lines from the L_{III} limit will be excited strongly while those from L_I and L_{II} are excited comparatively weakly by the general radiation of the primary x-rays. A source of constant high voltage was used and the tube run at constant voltage and current. A single crystal ionization spectrometer served to analyze the radiation emitted by the uranium. In order to compare the fluorescent intensities with those observed in primary x-rays, it was necessary to measure the absorption coefficients of uranium for its L-series lines. The following results were obtained:

Line	Wave-length	Atomic absorption coeff.
$L\gamma_1$	0.6163Å	2.8×10^{-20}
$L\beta_3$	0.7088	4.3 "
$L\beta_2$	0.7531	2.2
$L\alpha_1$	0.9087	2.8

After making all necessary corrections it was found that the relative intensity of the lines $L\alpha_1$ and $L\beta_2$ from the L_{III} level was the same in the fluorescent spectrum as in the primary spectrum observed by Allison (Phys. Rev. **32**, 1 (1928)).

29. The dynamic reflection of x-rays from ZnS. I. G. GEIB AND K. LARK-HOROVITZ, *Purdue University.*—It has been suggested by Ewald (Zeits. f. Krist. **65**, 251 (1927)) that for absorbing atoms the intensity distribution of an x-ray pattern depends on the direction of the x-ray beam relative to the crystal. ZnS crystals cut normally to the trigonal axis give plane parallel plates, one of which exhibits the 111, the other the -111 plane as has been shown directly by Lark-Horovitz in adsorption experiments with radioactive vapors (Proc. Vienna Acad. 1925). Using two such plates a Seeman slit spectrograph has been constructed with the $+111$ (Zn) and -111 (S) faces adjusted accurately in one plane to reflect gold, tungsten and tungsten-tantalum L radiation. These radiations contain lines on both sides of the Zn absorption limit and should therefore exhibit the effect predicted by theory. The photographic plate shows the L spectrum reflected simultaneously but with different intensity distributions from the Zn and S surfaces, due to absorption in the Zn atoms. The ratios (averages) of reflecting powers are:

Wave-length	1298.8	1285.0	1279.2	1273.8	1259.9	1242.0 XU
R_S (first order) / R_{Zn}	1.00	1.00	1.42	1.38	1.22	1.12
R_{Zn} (third order) / R_S	1.00	1.00	2.13	1.68		1.36

(in good agreement with the results of Coster (Zeits. f. Physik **63**, 345 (1930)).

30. A direct comparison of photographic and ionization methods of measuring x-ray intensities. ELMER DERSHEM, *University of Chicago.*—This investigation was undertaken to determine the relative precision which might practically be obtained by the photographic and ionization methods. The Mo $K\alpha_1$ line was isolated by crystal reflection and the ratio by which the intensity was reduced by passage through aluminum filters was measured by both methods. The photographic density determinations were made with the use of the photoelectric photometer previously described (R.S.I. **3,** 43 (1932)) and the ionization intensity measurements were made with an argon filled ionization chamber and Lindemann electrometer. The results show an average probable error for a single observation of 0.52 percent in the case of ionization measurements and of 2.1 percent when the photographic method is used. However, the ionization method is more subject to errors which may not be reduced by repeated measurements. The results show that the errors introduced by assuming the exact validity of the reciprocity law of blackening of a photographic plate by x-rays is not greater than one percent for intensity ratios up to twenty to one, if one assumes the ionization measurements to be correct.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 133—Eckhart

31. Absorption coefficients in optically excited mercury vapor. M. L. POOL AND S. J. SIMMONS, *Ohio State University.*—Mercury vapor at room temperature with various pressures of admixed purified nitrogen was optically excited by the resonance radiation from three quartz mercury arcs. From a fourth arc, magnetically deflected and water cooled, the radiation 4047, 2967 and 2752, all terminating on the 2^3P_0 state, was passed through the resonance tube of excited mercury vapor, and the absorption for each wave-length for various lengths of absorbing vapor was measured photometrically. It was found that the intensity of 2752 decreased nearly exponentially giving a linear absorption coefficient that varied slightly with the nitrogen pressure. However, for the lines 4047 and 2967 it was found that the simple exponential absorption law was not obeyed but that the fractional decrease in intensity per unit length of path decreased rapidly as the total length of the absorbing vapor increased. This peculiar decrease in intensity was further dependent upon the pressure of the admixed nitrogen. No other lines showed measurable absorption. The behavior of the 4047 and 2967 absorption for any given pressure may be adequately described by the sum of two exponentials with two quite different linear absorption coefficients.

32. The Zeeman effect of the spectra of SbII and SbIII. J. B. GREEN AND R. A. LORING, *Ohio State University.*—The spectra of SbII and SbIII have been investigated at field strengths of about 40000 gausses. Zeeman patterns of the lines of SbII show general agreement with Lang's (in print) classifications in the spectra, and quite general disagreement with D'Lavale's classifications (Proc. Roy. Soc. June, 1931). The spectrum of SbIII shows that the two principle valence electrons have practically $j-j$ coupling, so that, except for a few cases, the assignment of l-values to the levels is not possible. Lang's classification of the s^2p^2 configuration is in good agreement with Goudsmit's theory. The Zeeman patterns of SbIII are also in good agreement with Lang's classification (Phys. Rev. **45,** 435 (1930)) of this spectrum. Several of the lines of this spectrum, as well as of SbII show broadening and extra components due to the hyperfine structure. The levels of the s^2p^2 configuration of Sb II and the $s^2 \cdot s$, s^2p and sp^2 of Sb III show this effect most strongly, as is to be expected from the theory.

33. The two vector problem in Pb V and Bi VI. A. T. GOBLE AND J. E. MACK, *University of Wisconsin.*—The configurations $5d^{10}$, $5d^96s$, and $5d^96p$ of Pb V and Bi VI have been identified (except d^9p, $J=0$) from Arvidsson's wave-length list (Ann. d. Physik **12,** 787 (1932)). The coupling exhibited is the most nearly pure jj of any known in optical spectra. The d^9p levels lie in four separate groups, and the visually estimated intensities agree roughly with the expectations. The d^9s intervals, like similar intervals in the spectra of other very heavy elements, show some departure from the exact theoretical formulas (Houston, Laporte, Inglis) which can hardly be attributed to neighboring configurations. The exact formulas of Johnson (Phys. Rev. **38,**

1628 (1931)) have been applied to d^9p after transformation of the energy matrix to the jj system of representation to give the two coupling coefficients and five electrostatic parameters. These parameters, reapplied in the formulas, give roots in fair agreement with the observed terms, but in view of the inexactness of the d^9s check the approximate success in expressing the ten available intervals in terms of the seven parameters may be considered a significant check upon the theory. The line $d^9_{3/2}s)_2 - d^9_{3/2}p_{1/2})_1$ of Bi VI shows partially resolved hyperfine structure.

34. Dispersion of the Kerr effect in the near infrared. L. R. INGERSOLL AND W. R. WINCH, *University of Wisconsin.*—Measurements of the Kerr electro-optic effect have been made on carbon bisulphide, nitrobenzene, halowax, and a number of other liquids over a spectral region extending from the sodium lines to about 2μ, or some four times the wave-length range investigated by other observers. The method is a spectro-bolometric one, involving effectively the measurement of the minor axis of the ellipse into which the plane polarized light is converted by the electrostatic stress in the Kerr cell. The high potential of 2000 to 40,000 volts, or more, is furnished by a kenotron and condenser equipment. The Havelock formula $B = C(n^2-1)^2/\lambda n$ for the dispersion of the Kerr double refraction fits the measured dispersion fairly well for a short region beyond the visible spectrum—to $\lambda = 0.9\mu$ in some cases—but the discrepancy increases for longer wave-lengths.

35. The theory of refraction shooting. MORRIS MUSKAT, *Gulf Research Laboratory, Pittsburgh, Pa.*—Considerations of geometrical optics indicate that the limiting refracted rays travelling along the interface between two homogeneous elastic media should carry inappreciable amounts of energy. Nevertheless, the "first arrival" waves in refraction shooting processes which give linear time distance curves, can only be interpreted geometrically on assuming that they are due to such limiting rays travelling along the interface with the speed of the high velocity medium. A wave theory analysis of the problem resolves the difficulty. By an extension of Jeffrey's treatment for the case of fluid media to that of general elastic media it was found that *four* kinds of "refracted" waves of the above type will be produced upon the incidence at a plane interface of either a longitudinal or transverse spherical wave pulse. Two of the waves will be recorded as longitudinal waves and the other two as transverse. One of each pair effectively travels along the interface with the longitudinal velocity of the refracting medium and the other two travel with the transverse velocity. Their amplitudes vary inversely as the square of the distance from the source and correspond to vertical displacements of the same order as those due to the directly reflected waves.

36. Light intensities at different depths in water as determined by means of a quartz spectrograph. HENRY A. ERIKSON, *University of Minnesota.*—A quartz prism dispersing system in a specially designed housing was used for evaluating the intensities of different wave-lengths in the visible spectrum at different depths in water on Gunflint Lake on the northern border of Minnesota. The spectrum was photographed at different points down to 70 ft. and from these the intensities of the different wave-lengths were evaluated from characteristic curves obtained from standard exposures using wire screens. It was found that the variation of the intensity with depth was exponential in the case of some wave-lengths but not in the case of all. From the results obtained absorption constants were obtained for the different wave-lengths.

37. A twenty-one foot grazing incidence vacuum spectrograph. P. GERALD KRUGER AND F. S. COOPER, *University of Illinois.*—A grazing incidence vacuum spectrograph, for a twenty one foot focal length grating, ruled 30,000 lines per inch, has been set up and adjusted. The angle of incidence is 79 degrees. This gives the following dispersions at various wave-lengths between 0 and 500A.

λ	Dispersion
100A	0.332Å per mm
150	0.360
200	0.387
300	0.435
400	0.477
500	0.516

Copper electrodes were used in a "hot spark" for the light source during adjustment. The power was supplied at 100,000 volts d.c., by a four kenotron bridge set. The lines obtained were very sharp so that it was possible to measure their wave-lengths more accurately than has been done previously in this region.

38. A high pressure spectrometer. FRANKLIN E. POINDEXTER AND LOUIS E. JAMES, *St. Louis University.*—A spectrometer has been constructed for the study of the change in the refractive index of liquids with pressure. The pressure on the liquid prism is measured directly by means of a plunger and lever. The index of refraction of water for each of the Hg lines 4359A, 5461A, and 5790A has been obtained at a series of pressures from 1 to 1440 atmospheres. We find that the Lorentz-Lorentz relation, $(n^2-1)/(n^2+2)\cdot 1/\rho = K$, where n = index of refraction, ρ = density, and K = constant does not hold; i.e., the K's at the lowest and highest pressures are:

	K 1 atmosphere	K 1440 atmospheres
4359A	0.2106	0.2092
5461A	0.2074	0.2070
5790A	0.2067	0.2062

39. The influence of pressure on the formation of the latent photographic image, particularly its effect on reversal in the region of Solarization. KARL A. MARING, S.J., *St. Louis University. (Introduced by F. E. Poindexter.)*—Photographic materials were exposed, so that a central region was under pressure and a rim area without pressure. The pressure area showed a reduction in density over the rim area depending, in amount, on the exposure and the pressure. This reduction in density fell off with increasing exposure, gained with increasing pressure. However, this reduction of the density is not a linear factor of either exposure or pressure. In the region of solarization, a marked acceleration of reversal is noted in the pressure region. This pressure effect seems to call attention again to the photomechanical disintegration theory of the latent image formation.

SATURDAY AFTERNOON AT 2:00 O'CLOCK

Room 32—Ryerson

Papers No. 41 and 44 will be read by title.

40. Direct measurement of the gravitational effect of the moon. KENNETH HARTLEY, *Hartley Gravity Balance Corporation, Houston, Tex.*—The sensitivity of the gravity balance described in the March number of Physics is such that a correction must be made for the effect of the attraction of the moon. This lunar effect has been measured by hourly readings over one complete cycle and agrees, within the observational error, with the effect calculated for the vertical component of the pull of the moon without any compensation for the centrifugal effect of the earth's motion around the center of gravity of the system. The effect has a period of 24.8 hours and not 12.4 hours as the tides, there is no trace of the twelve-hour period. Values of gravity plotted against time follow accurately a sine curve which shows a small time lag as compared with the theoretical curve. This does not seem to be accidental but has not been explained.

41. Thermal expansion of antimony. PETER HIDNERT AND H. S. KRIDER, *Bureau of Standards, Washington, D. C.*—Measurements were made on the linear thermal expansion of three samples of cast antimony between room temperature and 560°C and the data were correlated with available results obtained by previous investigators to 300°C. The minimum and maximum values for the coefficients of expansion of the three samples are given in the following table.

Temperature range °C	Average coefficients of expansion per degree centigrade 10^{-6}
20 to 60	8.5 to 10.8
20 to 100	8.4 to 11.0
20 to 200	8.7 to 11.3
20 to 300	9.2 to 11.4
20 to 400	9.2 to 11.5
20 to 500	9.5 to 11.6
20 to 550	9.7 to 11.6

A manuscript giving additional details and indicating the cause of the differences obtained in the expansion of different samples of antimony, is being prepared for publication in the Bureau of Standards Journal of Research.

42. Refractory materials for melting pure metals. H. B. WAHLIN, O. D. FRITSCHE, AND J. F. OESTERLE, *University of Wisconsin.*—A study of various refractories has shown that porcelain as well as magnesia crucibles volatilize and reduce sufficiently, when heated in a vacuum, to contaminate pure metals contained in them. Crucibles of pure, fused thorium oxide are the most satisfactory and will withstand heating in a vacuum for long periods of time. Special shapes of crucibles may be readily prepared by using moulds made of a fusible alloy which is melted off before firing. The crucibles should be fired to a temperature of 1800°C, care being taken to prevent the formation of thorium carbide which, due to interaction with the moisture of the air, will cause the crucibles to break up.

43. The Joule-Thomson effect in helium. J. R. ROEBUCK AND HAROLD OSTERBERG, *University of Wisconsin.*—Isenthalpic curves have been measured from −190° to +300°C. They are straight lines over the 200 atm. range except at the lowest temperature. Their slope, μ is negative over the whole range. At −190°C μ is increasing sharply with falling temperature moving toward the known-positive value at liquid hydrogen temperatures. From −50 to 150° μ decreases slowly and linearly. It goes through a minimum at about 200° and increases slowly thereafter. The free expansion coefficient, η calculated from these data, is negative and decreasing with rising temperature, between −50 and 200°C. This trend of η makes very improbable any prediction that helium will become a perfect gas at any temperature. With falling temperature η apparently becomes positive. These facts are difficult to reconcile with the older conception of the van der Waals forces but they may be explained qualitatively, at least, by restricting the attractive and repulsive forces to a very small fraction of the mean free path. The data are being used to calculate the Kelvin temperature of the ice point from the helium thermometer work.

44. Oscillations produced by beads of corona discharges. J. TYKOCINSKI TYKOCINER, *University of Illinois.*—The investigation of oscillations due to single bead discharges (Phys. Rev. **39**, 189 (1932) Abs. 52) has been extended to cases when a number N of beads act simultaneously. If the discharge consists of beads equal in size and brightness and distributed at regular distances along the negatively charged wire, the frequency is N times smaller than that obtained for a single bead, provided that the pressure, P, and the total corona current, I, remain constant. For the frequency f the relation was found $f = CIM/N$ where M is the number indicating the harmonic and c is a constant. For beads differing in size and distributed irregularily along the wire, oscillations of a complex character are obtained which contain as many fundamental frequencies as there are beads on the wire. The linear relation between f and I ceases when the current through a single bead reaches a definite value I_p. With further increase of current the rate of frequency increase diminishes and, from a critical value I_c on, the frequency decreases until, at a current $2I_c$, oscillations stop altogether. These relations were investigated for pressures within 5–60 mm Hg. The appearance of the bead gradually changes with the current, but at the characteristic point when oscillations stop sudden changes in the appearance can be observed.

45. Some experiments on electrets. O. J. JOHNSON AND P. H. CARR, *Iowa State College, Ames, Iowa.*—Electrets have been made after the manner of Eguchi from a mixture of Car-

nauba wax and rosin in electric fields as small as a few hundred volts per centimeter. A series of experiments was made in which the electric field was applied to the wax mixture at different temperatures and allowed to remain until the wax cooled to room temperature. Another series was made in which the electric field was applied when the wax was molten but was removed from each successive sample when it had cooled to a temperature lower than that at which the field was removed from the preceding sample. The strength of the electret resulting from each sample was measured. Results indicate that the molecules of the wax mixture become fixed in their polarized positions, so that random reorientation is negligible, at a temperature definitely lower than the temperature at which solidification takes place. Electrets have also been made from molten sulphur, but their properties have not been studied.

46. The measurement of the piezoelectric deformations of quartz and tourmaline plates by means of a modified optical lever. GEORGE A. FINK, *Iowa State College.* (*Introduced by G. W. Fox.*)—The observation of the piezoelectric deformation of quartz or tourmaline plates used for radio frequency oscillators requires a more sensitive measuring scheme than that afforded by direct optical interference or the ordinary type of optical lever. With a potential difference of 500 volts between the crystal electrodes, a deformation of only 10A is to be expected. To amplify such small movements, a lever has been built having an amplification ratio of 1866, such that, by interferential observation of a mirror on the long end, a movement of the short end of only 0.15A can be detected. Values of the piezoelectric constants for quartz and tourmaline as determined from the inverse effect are in fair agreement with those found by previous observers from the direct effect. The structure of the quartz crystals was found to be very non-uniform; various crystals and different parts of the same crystal plate giving results differing by more than the experimental error.

47. Modes of vibration of piezo-electric crystals. N. H. WILLIAMS, *University of Michigan.* —(a) A crystal is made to oscillate by subjecting it to the action of an air wave produced at a considerable distance from the crystal by a jet of air escaping from a small tube. The piezo-electric charge developed on the surface of the crystal as a result of the oscillation is mapped out by means of a tuned amplifier, and the vibration is analyzed into a fundamental and many overtones. The crystals are long in one dimension and the vibrations are along the length. Under these conditions the overtones are approximate harmonics. (b) Exciting the crystal electrically by means of two tubes and especially designed electrodes, any harmonic up to the tenth can be produced. The crystal usually has only one mode of vibration for each pair of electrodes.

48. A non-thermionic amplifier tube. HERBERT J. REICH, *University of Illinois.*—Grid control of a glow discharge is obtained in this tube by so designing and placing the grid that it is out of the direct path of the discharge between anode and cathode. Variation of the grid potential modifies the electric field in such a manner as to control the number of electrons which move through a distance sufficient to produce ionization. By maintaining the static grid potential at such a value that the number of positive ions which strike the grid is equal to or slightly in excess of the number of electrons, the grid current may be limited to less than ten microamperes. The discharge is at all times under control of the grid and may be completely extinguished by it. The gas pressure is found to be very important in obtaining satisfactory operation. The relation of structural parameters to tube constants is being studied, but little attempt has yet been made to improve the amplification characteristics. A conservative average for tubes made during the preliminary investigation gives values of 3 for amplification factor and 100 micromhos for mutual conductance. With proper design and choice of gas pressure, little or no ballast resistance is required.

49. The use of vacuum tube electrometers for measuring the potentials of high resistance cells. ROBERT E. BURROUGHS AND J. E. FERGUSON, *Purdue University.*—By using the relation between the grid potential and the plate current of a thermionic vacuum tube one is able to construct an electrometer of high sensitivity. Such electrometers have been used in the measurements of electromotive forces of cells whose internal resistances are very high. In these measurements the vacuum tube is operated with its grid at floating potential so the current

drawn from the cell will be very small. The cell potential is then measured by applying a compensating potential in series with the cell in the grid circuit of the electrometer. Using a null method, when this compensating potential is adjusted so as to give zero indication on the electrometer it is a measure of the electromotive force of the cell. This method gives satisfactory results for cells whose resistances are below 10^{11} ohms. For resistances higher than this a difficulty is encountered. The current to the grid of the vacuum tube is so small that the time required to change the grid potential, sufficiently to secure a balance with precision, is of such length that lack of circuit stability renders the method useless.

SUPPLEMENTARY PROGRAM

When two or more papers are offered by the same member, one only of these will be assigned a place on the regular program, while the others will be placed in a supplementary program, to be called for if time permits.

Papers received after the program has been printed will be placed in the supplementary program.

The papers in the supplementary program may be called for at any session in Room 133, Eckhart Hall.

50. Improved burner for singing flames. Overtones in vibrating strings. JOHN J. HOPFIELD, *Basic Science Division, A Century of Progress, Chicago.* (*Introduced by H. G. Gale.*)—By using a suitable double burner with the flames at different heights instead of a single flame, the flames vibrate to the resonance tones of a pipe even when the larger flame was several inches long. It was found that the smaller flame starts the singing and the larger one responds. (Demonstration.)

By using a modified 120 cycle tuning fork operated on 60 cycle current, one can produce not only the 120 cycle fundamental in a Melde string but also the note of frequency 60 and many integral multiples of these tones. These are made evident in the point symmetrical form of the standing waves in the string, and also they can be separately sounded in a tube fitted with a sliding plunger and held near a disc attached to the side of the string. (Demonstration.)

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